HEAVY QUARK PRODUCTION IN THE SEMIHARD QCD APPROACH AT HERA AND BEYOND

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Processes of heavy quark production at HERA, TEVATRON and THERA energies are considered using the semihard (k_T factorization) QCD approach with emphasis on the BFKL dynamics of gluon distributions.

The experimental results on $b\bar{b}-$pair production cross sections obtained by the H1 and ZEUS Collaborations at HERA[1] and D0 and CDF Collaborations at TEVATRON[2] provide a strong impetus for further theoretical studies. Comparisons of these results with NLO pQCD calculations show that they underestimate the cross sections at HERA and TEVATRON energies. Therefore, it looks certainly reasonable to try a different approach.

In this work we focus on the description of $b\bar{b}-$pair cross sections at HERA and TEVATRON in the so called semihard (k_T factorization) QCD approach (SHA)[3,4], which we have applied earlier to open charm[5] and J/Ψ photoproduction at HERA (see in ref.[5]). We also discuss the sensitivity of our theoretical results[6] to the BFKL type dynamics[7] which may be investigated in the photoproduction of D^* and J/Ψ mesons at THERA energies.

In SHA, the unintegrated gluon distribution $\varphi_G(x, k_T^2)$ is connected with the conventional gluon density $xG(x, Q^2)$ by the following relation

$$xG(x, Q^2) = xG(x, Q_0^2) + \int_{Q_0^2}^{Q^2} dk_T^2 \varphi_G(x, k_T^2), \tag{1}$$

where Q_0^2 is the collinear cutoff parameter. We used the results of ref.[4] for the

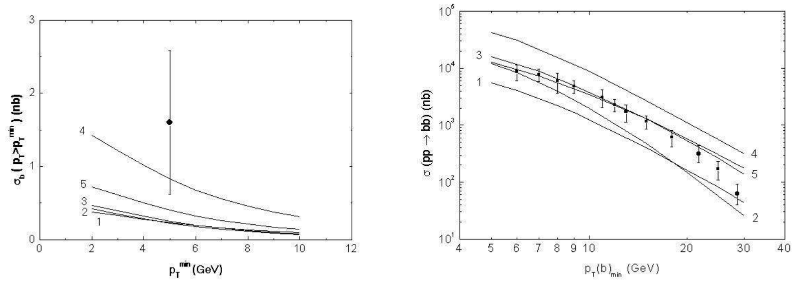

Figure 1. The cross sections of $b\bar{b}$ production $\sigma(p_T > p_T^{min})$ at HERA (left panel) and TEVATRON (right panel): curves 1, 2, 3, 4 and 5 correspond to the MT, GRV, RS, LRSS and BFKL parametrizations of gluon distribition.

off mass shell parton cross sections, and we used several different parameterizations for the unintegrated gluon distribution (see ref.[5] for details), namely: the LRSS[3], RS[8] and the so called BFKL [9] parameterizations. We used the following set of SHA parameters: Q_0^2 =4, 2 and 1 GeV^2 in (1) for the RS, LRSS and BFKL parameterizations; in the case of the BFKL parameterization the parameter $\Delta = 0.35$[5]; everywhere the charm and beauty quark masses are m_c =1.5 GeV and m_b =4.75 GeV.

The results of our calculations for the total cross section of inelastic $b\bar{b}$ photoproduction at HERA as compared to H1[1] data are published in the pa-

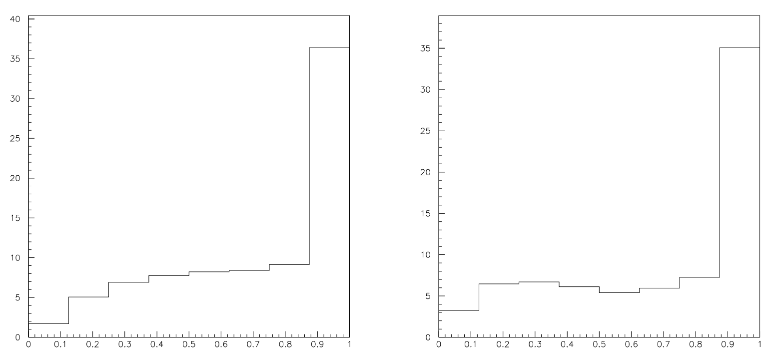

Figure 2. The differential cross section $d\sigma/dx_\gamma$ (nb) for $Q^2 < 1$ GeV^2 with BFKL (left panel) and CCFM (right panel) unintegrated gluon distributions at THERA.

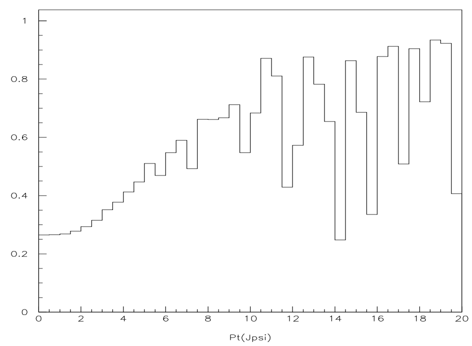

Figure 3. The fraction of J/Ψ mesons in helicity zero state (degree of spin alignment).

per by Lipatov, Saleev, Zotov[5]. We have shown there that the H1 data are well described by the LRSS parametrization and by the the BFKL parametrization but only with as small m_b as m_b =4.25 GeV in the latter case. In Fig. 1a we show our results for the total cross section of inelastic $b\bar{b}$ photoproduction at HERA compared to ZEUS data[1]. We see that only the LRSS parametrization describes the ZEUS data (at m_b =4.75 GeV). In contrast with this, the cross section for $b\bar{b}$ production at TEVATRON[2] is described by the BFKL and RS parametrizations very well (Fig. 1b). The LRSS parametrization (at the same values[5] of parameters and normalization) overshoots the D0 (and CDF) data.

In the ref.[10] the calculations of the associated charm and dijet production cross section have been made within the SHA with BFKL and CCFM[11] unintegrated gluon distributions at HERA energies. The attention was focused there on the variable x_γ, which is the fraction of the photon momentum contributed to a pair of jets with largest p_T. The results of the similar calculations made for THERA conditions are shown in Fig. 2 as a futher test of the underlying dynamics. The existence of the wide plateau at $x_\gamma < 0.9$ seen in the fugure comes from the noncollinear gluon evolution, which generates gluons with non-negligeable transverse momentum. In a significant fraction of events the gluon emitted close to the quark box appears to be even harder than one or even both of the quarks produced in hard interaction.

The effects of initial gluon off-shellness may be, best of all, seen in the transverse momentum spectra of J/Ψ mesons[12]. In contrast with the conventional (massless) parton model, the SHA shows that the fraction of J/Ψ mesons in the helicity zero state increases with their transverse momentum

p_T. A deviation from the parton model behaviour becomes well pronounced already from $p_T > 3$ GeV at HERA energies[12], and at $p_T > 6$ GeV the helicity zero polarization tends to be dominant. The same effect is seen in Fig. 3, where we show the results of the calculations[6] of the ratio $\sigma_{h=0}/\sigma$ for J/Ψ photoproduction at THERA conditions made with the BFKL unintegrated gluon distribution.

The examples considered in this paper demonstrate the effects of the BFKL gluon evolution on the important and experimentally measurable quantities, such as the event topology or vector meson spin alignement. At present, the theoretical predictions made for HERA and TEVATRON conditions have found their experimental confirmation. A further investigation of the relevant effects at THERA collider can put our understanding of the hadron structure on even more solid grounds.

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